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Original Article

Assessment of green space connectivity amid land cover changes: a case study of Delta State, Nigeria

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ABSTRACT

Green spaces (GS) are land cover with ecological and social traits that complement urban physical structure. This study evaluated GS within land cover changes in the Delta State of Nigeria for environmental management. Data for this study were obtained from satellite (Landsat) imageries of the years 1994, 2004, 2014, and 2024 and were classified into four land cover classes: gray (built-up areas), brown (beaches, mountains, or areas with no vegetation), blue (water bodies), and green spaces using the maximum likelihood method of supervised classification, and the space changes were implemented via contextual time analysis. The green spaces were further classified into forests, agriculture, grass/shrubland, urban trees, and wetlands using the methods. The areas for each class were computed and subjected to descriptive statistics. The result showed an increase in gray spaces and a serious loss in green spaces. Forested lands decreased from 6234.3 km² in 1994 to 5732.1 km² in 2004, corresponding to about 51% to 47%, respectively, before decreasing further to about 30% in 2014 and slightly increasing to about 35% by 2024. Agricultural lands noticed their highest (4715.3 km^2) increase from 2004 to 2014. Between 2014 and 2024, agricultural land noticed a high decrease (-3602.8 km^2), giving rise to an increase in forested lands (620.7 km^2), grass/ shrub lands (863.2 km^2), and 926.4 km^2 of wetlands. Tree planting is recommended, especially in urban areas of the state, to increase the area of green spaces.

K E Y W O R D S : *Geographic Information System, Land Use, Remote Sensing, Urban forestry, Urban trees*

INTRODUCTION

Green spaces (GS) offer an ideal escape from the stress and hustle of daily life, due to their impressive social and ecological influences (Barker, 1968; Karade *et al*., 2017; Addas, 2023). Green space houses a relatively large number of animal and plant species and thus potentially represents an important role in maintaining biodiversity in an urban context (Philippe, 2007). Maintaining this diversity has been recognized as a major environmental issue and priority at both the international and local levels (Philippe, 2007). The importance of GS has been recognized and considered a long-term comprehensive tool for the protection and maintenance of environmental sustainability by providing ecosystem services to users (Vargas-Hernandez *et al*., 2018). In Nigeria there is limited study on GS covering States; according to Adegun (2021), a significant proportion of the studies on GS were conducted in the context of Lagos and Abuja, being the commercial and administrative capitals respectively. Hence, studies mostly concentrated on Urban Green Spaces (UGS) and Land Use/Land Cover (LULC).

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Land cover (LC) is the observed physical cover on the earth's surface, including vegetation (natural or planted) and human constructions, LC information is also important to policy and decision-makers relative to changes in land cover areas and conditions associated with key ecosystem services (Townshend *et al*., 2008). When Land use and land cover are treated jointly, they represent both the physical cover and human imprints on the land (Abbas, 2023). Liu *et al*. (2021) explained that the expansion of land use, especially in urban areas, has led to a reduction in green spaces, with buildings, roads, transportation hubs, bridges, land reclamation, and concrete surfaces replacing vegetation. Despite the importance of GS, there is a paucity of information on the LC and green spaces in most states of developing countries, such as Delta in Nigeria.

Delta State is in the Niger Delta area of Nigeria. The Niger Delta is of global importance for biodiversity conservation, owing to its extraordinary biodiversity (World Bank, 1995; Ugochukwu & Ertel, 2008). The region's biodiversity is under serious threat due to the rapid rate of environmental degradation occasioned by oil and gas exploration activities. The rapid urbanization, industrialization, and agricultural expansion have resulted in the fragmentation and degradation of green spaces in the region. A study by Uwagboe *et al*. (2020) found that oil exploration and extraction activities in the Niger Delta region contribute to increased pollution, posing risks to both the environment and human health.

Existing studies focus on urban areas (Akpovwovwo, 2020; Akintunde-Alo *et al*., 2024) and land use land cover of specific areas within the State (Wizor & Okugini, 2020; Oyem & Igu, 2021; Ugbelase *et al*., 2021; Iwebelua *et al*., 2024) resulting in gaps in understanding their overall status. Hence, this study aimed to use remote sensing (RS) and geographic information system (GIS) techniques to evaluate green spaces and land cover changes in the Delta State of Nigeria from 1994 to 2024 for ecological management.

MATERIALS AND METHOD

Study Area

Delta State is located within the southern part of Nigeria, it lies between longitudes 5°00'E and 6°45'E and latitudes 5°N and 6°30'N (Figure 1), covering a land area of 16,842 square kilometers. Delta State is bordered by Edo to the north, Ondo to the northwest, Anambra to the east, and Bayelsa and Rivers to the southeast (NDBMG, 2024). Delta State is located in the tropical region and experiences a variable climate, transitioning from a humid tropical climate in the south to a sub-humid climate in the northeast. As humidity decreases towards the north, the dry season becomes more pronounced. The average rainfall is approximately 266.5 mm in the coastal areas and 190.5 mm in the far north, with the heaviest rainfall occurring in July. Temperatures rise from the south to the north. The mean monthly temperature ranges from 30-44ºC (NDBMG, 2024).

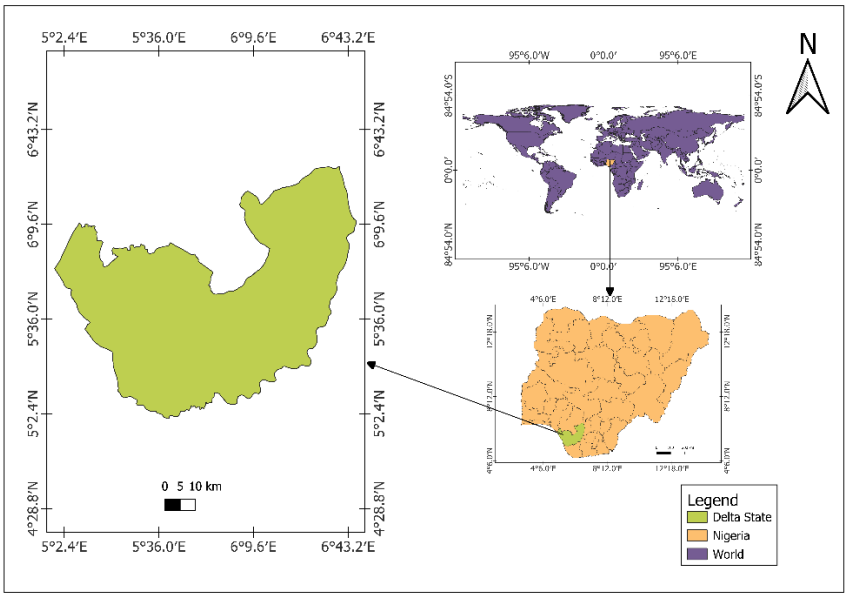

Figure 1: Map the World showing Delta State, Nigeria

Data Collection, Processing, and Analysis

This study utilized atmospherically corrected Landsat satellite images of the years; 1994, 2004, 2014, and 2024 from the United States Geological Survey (USGS) and Earth Explorer database (http://earthexplorer.usgs.gov). The Landsat images were processed using ArcGIS software to classify four land cover categories. Radiometric/Geometric corrections were done on the images using the raster calculator in the arc toolbox. This was achieved by multiplying the specific band with its reflectance_Multi_Band value and adding the obtained value with the value of the band's Reflectance_Add_Band, both divided by the Sine of the sun elevation. The bands were made into composites for ease of visual interpretation, and mosaicked to become one image containing the entire Area of Interest. A supervised classification using the maximum likelihood method was applied, utilizing various band composites as described in Table 1 below. This is a pixel-based classification that categorises the images based on the homogeneity of image pixel spectral information as identified by the trainer.

Data analysis was performed using ArcMap (version 10.7.1) to quantify Land Cover (LC). The study identified and analyzed four classes as described in Table 1; gray, brown, blue, and green spaces, for years 1994, 2004, 2014, and 2024 with each class having the same color as its name. Further classification was done on the green spaces, as it is the main focus of the study, namely; forests, agriculture, grass\shrubland, urban trees, and wetland (Table 2). The area of each classified land cover type was calculated in square kilometers using ArcMap's conversion tools.

Land cover changes (LCC) over the study period were implemented via a contextual time approach; this involves subtracting the area value of each LC class from the previous year to give either the positive or negative LCC over a period of time. This systematic approach facilitated a comprehensive evaluation of LCC over the four decades studied.

RESULT AND DISCUSSION

The land cover map displayed the distribution of space classes of Delta State of Nigeria for the years 1994, 2004, 2014, and 2024 (Figure 2A to 2D, respectively). The green spaces were more prominent in 1994 and 2004. The estimated areas along with their percentage for each land cover class—Gray Spaces, Brown Spaces, Blue Spaces, and Green Spaces (Forests, Agriculture, Grass/Shrubland, Urban Trees, and Wetlands) for Delta State are illustrated in Table 3 and Figure 3A. The results revealed that Gray Spaces increased significantly from 16% (2688.9 km²) in 1994 to 39% (6528.5 km²) in 2024, with a notable rise to 20.4% in 2004 and 27.2% in 2014 (Table 3 and Figure 3A). In contrast, Brown Spaces exhibited notable fluctuations, rising sharply to 22% (3643.2km²) in 2004 before declining to about 8% in 2014 and further decreasing to 3 % by 2024 (Table 3 and Figure 3A). Blue Spaces experienced a decline throughout the period, decreasing from about 11% in 1994 to 5% in 2004 and further decreasing to about 3% in 2014 and 2024 (Figure 3A).

Table 1: Characteristics of Satellite imageries used for the study (Spatial Resolution= 30 m)

Satellite (Sensor)/ Year	Spectral Bands	Wavelength (µm)	Path and Row
Landsat 5 (TM) 1994	4 (Near-infrared)	0.76 - 0.90	189, 056 189, 057
	3 (Red)	0.63 - 0.69	
	2 (Green)	0.52 - 0.60	
Landsat 7 (ETM+) 2004	4 (Near-infrared)	0.77 - 0.90	189, 056 188, 056
	3 (Red)	0.63 - 0.69	190, 056
	2 (Green)	0.52 - 0.60	189, 057
Landsat 8 (OLI) 2014	7 (Short-wave infrared 2)	2.11 - 2.29	188, 062 189, 056 190, 056
	5 (Near-infrared)	0.85 - 0.88	189, 057
	3 (Green)	0.53 - 0.59	
Landsat 9 (OLI-2) 2024	7 (Short-wave infrared 2)	2.11 - 2.29	190, 056 189, 057
	5 (Near-infrared)	0.85 - 0.88	
	3 (Green)	0.53 - 0.59	

TM= Thematic Mapper, ETM+= Enhanced Thematic Mapper Plus, OLI= Operational Land Imager

Table 2: Land Cover Classes

LC Classes	Description
Gray Spaces	These are built-up areas, that include commercial, industrial, and residential buildings, as well as transportation infrastructure.
Brown Spaces	These include beaches, sandy areas, `rocks, mountains, and areas of land with little or no vegetation cover.
Blue Spaces	These areas are covered in water permanently. They include rivers, streams, dams, and lakes.
Green Spaces	***Forests:*** An area of land spanning over 0.5ha, dominated by trees of at least 5 meters in height and a canopy cover of>10 %, (FAO, 2020). ***Agriculture:*** An area of land cultivated with arable crops and other plants. These include farms, gardens, and nurseries. ***Grass/Shrubland:*** An area of land covered with grasses, herbs, shrubs, and very few scattered trees. ***Urban Trees:*** These are areas of green cover in towns and cities. It includes trees found around built-up areas. ***Wetlands:*** are defined as areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters (Ramsar Convention Secretariat 2007 cited in Dauda, 2014).

The study highlights how land cover impacts the green spaces in Delta State, Nigeria. The continued increase in the gray spaces (built-up areas) throughout the period under investigation is an indication of the urbanization of Delta State. This corroborates the fact that Delta State which was once an integral part of the old western region of Nigeria became an autonomous entity on August 27, 1991(NDBMG, 2024). Rapid urbanization could be due to the need to build infrastructures such as commercial, industrial, residential buildings, and road networks among other infrastructures required for State and Local Government Area (LGA) offices, staff quarters, etc. This was also evident as NDBMG (2024) reported that Delta State started with twelve (12) LGAs in 1991 and further increased to nineteen (19) LGAs in 1997. Hence this implied the conversion of other land covers into built-up areas, this could also be seen in the relative decrease in the brown, blue, and green spaces.

For green spaces, the pooled result showed a fluctuation with a decrease from 12222.9 km² (73%) in 1994 to 8952.0 km² (53%) in 2004, followed by an increase to about 62% in 2014 and a decrease to about 55% in 2024 (Table 3 and Figure 3A). Forests decreased from 6234.3 km² in 1994 to 5732.1 km² in 2004 corresponding to about 51 to 47%, respectively, before decreasing further to about 30% in 2014 and slightly increasing to about 35% by 2024 (Table 3 and Figure 3B). Agricultural land saw an initial before decreasing to about 13% by 2024 (Figure 3B). Grass/ Shrubland showed a sharp decrease from about 43% in 1994 to only about 2% in 2004. Urban Trees remained minimal throughout the study period. On the other hand, wetlands showed fluctuations from about 4% in 1994 to 18% % in 2004, a decrease to about 9% in 2014, and a rise to 17% by 2024 (Figure 3B), hence the corresponding land areas were presented in Table 3.

According to Nwilo and Badejo (2005), the coastal areas of the Niger Delta are the home to oil exploration and exploitations in Nigeria (This is largely due to the huge deposits of crude oil and natural gas deposits within the region. The World Bank report of 2002 succinctly stated that Rivers and Delta states alone produced about 75% of Nigeria's petroleum, which represents over 50% of the national government's revenues, hence, the reason for urbanization. Freire (1993) pointed out that the boom in urbanization in these areas if not properly managed has implications for sustainable development. This agrees with Iwebelua *et al*. (2024) built-up areas of the East-West Road Corridor in Delta State increased by 35%, largely due to the expansion of residential and commercial developments while Agricultural land decreased by 20%, and forest cover was reduced by 10% due to land conversion for urban uses.

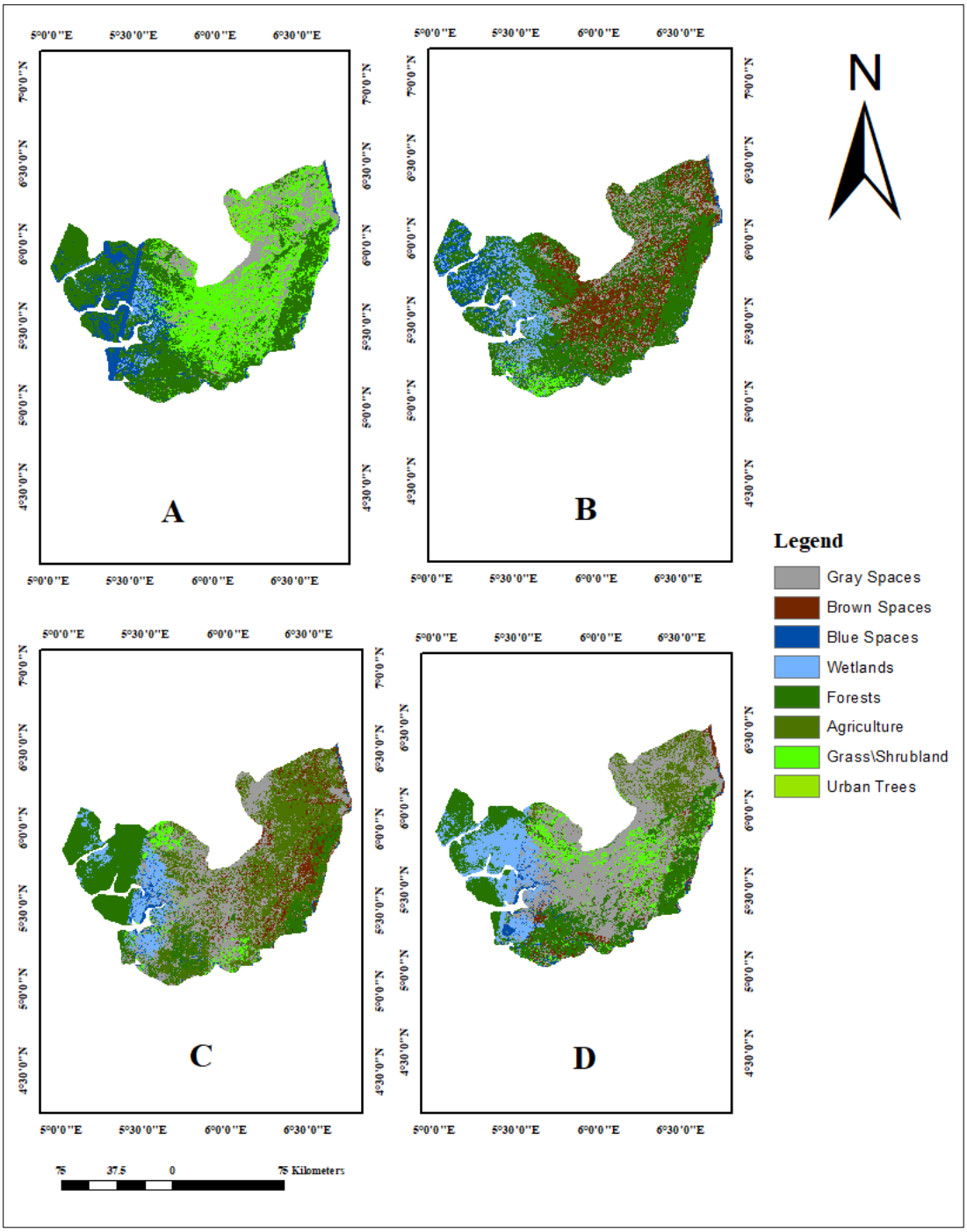

Figure 2: Land Cover Model of 1994-2024 showing the green spaces of Delta State

Table 3: Land cover/Green Space distribution for Delta State from 1994-2024

Class	Year			
	1994	2004	2014	2024
	Spaces (Land cover km^2)			
Gray Space	2688.9	3426	4573.6	6528.5
Brown Space	146.7	3643.2	1370.3	577.5
Blue Space	1764.1	801.4	418.9	446.9
Green Space	12222.9	8952	10459.7	9269.6
Total	**16822.5**	**16822.5**	**16822.5**	**16822.5**
	Green Space (km^2)			
Forests	6234.3	5732.1	3705.2	4325.8
Agriculture	119.2	471.5	5186.8	1584.0
Grass/Shrubland	5195.6	287.4	395.7	1258.9
Urban Trees	182.1	215.8	29.4	31.8
Wetlands	491.7	2245.2	1142.7	2069.1
Total	**12222.9**	**8952**	**10459.7**	**9269.6**

The changes in the land cover and green spaces were presented in Table 4 and Figures 3C and 3D. The results indicated an average rate of change of 128.0 km^2/yr for gray spaces, 14.4 km^2/yr for brown spaces, -43.9 km^2/yr for blue spaces, and -98.4 km^2/yr for green spaces in Delta states of Nigeria. The green space showed a decrease (-3270.9 km^2) between 1994 and 2004, an increase (1507.7 km^2) in green spaces was recorded between 2004 and 2014, and a decrease of -1190.1 km^2 between 2014 and 2024 (Table 4 and Figure 3C). The result of further analysis on green spaces showed fluctuations in all the green space sub-classes, with an average rate of change of -63.6 km^2/yr for forests, 48.8 km^2/yr for agricultural land, -131.2 km^2/yr for grass/ shrubland, -5.0 km^2/yr for urban trees and 52.6 km^2/yr for wetlands (Table 3).

Further analysis results on specific green spaces indicate a continuous increase in agricultural land and a decrease in forest land. This was supported by separate Land use/ land cover (LULC) and research conducted in different LGAs of Delta State; Wizor & Okugini (2020) reported an increase in Agricultural land and a decrease in forest areas in Ukwuani LGA between 1990 and 2014; Ugbelase *et al*. (2021) reported that Farmlands accounted for 36.34% while forest accounted for 20.42% in of the year 2002 total LULC class of Aniocha north LGA and Iwebelua *et al*. (2024). Hence, the decrease in forest area could put the environment at risk of biodiversity loss, pollution, food insecurity, alteration of habitats, and destruction of ecosystems (Ugboma, 2014).

Table 4: The Land Cover/Green Spaces Changes of Delta State from 1994-2024

Class	2004-1994 Change (km^2)	Rate of change (km^2/yr)	2014-2004 Change (km^2)	Rate of change (km^2/yr)	2024-2014 Change (km^2)	Rate of change (km^2/yr)	Average Rate of change (km^2/yr)
`			Space (Land cover)				
Gray Space	737.0	73.7	1147.7	114.8	1954.9	195.5	128.0
Brown Space	3496.5	349.6	-2272.9	-227.3	-792.8	-79.3	14.4
Blue Space	-962.7	-96.3	-382.4	-38.2	28.0	2.8	-43.9
Green Space	-3270.9	-327.1	1507.7	150.8	-1190.1	-119.0	-98.4
			Green Space				
Forests	-502.3	-50.2	-2026.9	-202.7	620.7	62.1	-63.6
Agriculture	352.3	35.2	4715.3	471.5	-3602.8	-360.3	48.8
Grass/ Shrubland	-4908.1	-490.8	108.3	10.8	863.2	86.3	-131.2
Urban Trees	33.8	3.4	-186.5	-18.6	2.4	0.2	-5.0
Wetlands	1753.5	175.4	-1102.5	-110.3	926.4	92.6	52.6

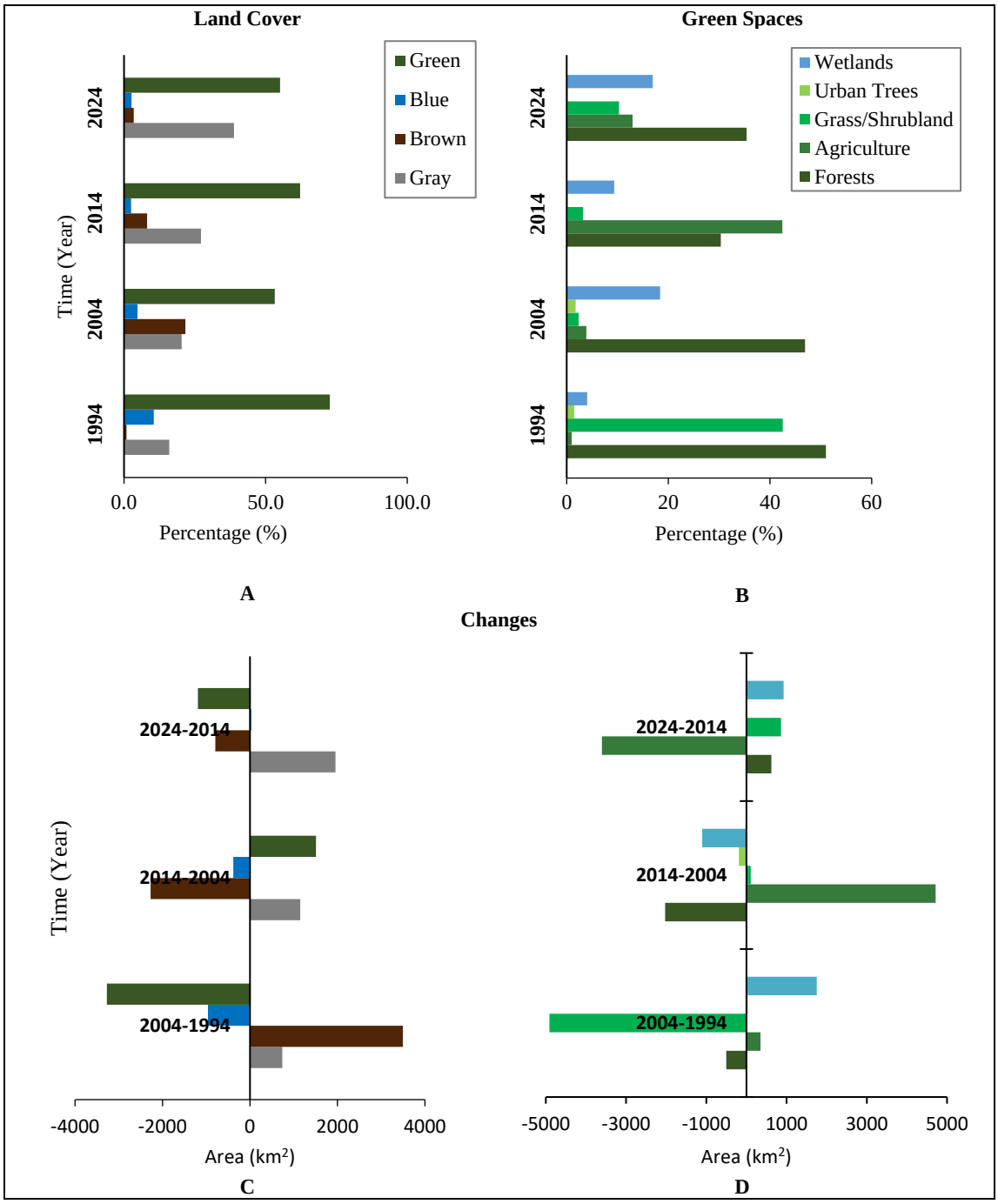

Figure 3: Land cover, green spaces, and their change statistics of the study area

Furthermore, Agricultural land noticed its highest (4715.3 km^2) increase between 2004 to 2014. Between 2014 and 2024, agricultural land noticed a high decrease (-3602.8 km^2), giving rise to an increase in forested lands (620.7 km^2), grass/ shrub lands (863.2 km^2), and 926.4 km^2 of wetlands (Figure 3D). However, the decrease in Agricultural lands and a slight increase in forested lands, grass/ shrub lands, and wetlands in recent years could be a result of conservation efforts. The importance of trees in urbanization is still quite unknown as urban trees have rarely had prominence in the State. Urban trees have been <1% of land area over the years under study, despite the increase in gray spaces, highlighting insufficient urban greening efforts amid rapid development pressures. On the other hand, an increase in wetlands and a reduction in blue spaces were visible over the years under investigation. This could imply the conversion of water bodies into wetlands. In Delta State, river Niger drains the eastern flank of the state and discharges into the sea through its several distributaries such as the Forcados, Escravos, and Warri rivers and creeks (NDBMG, 2024) which may have partly contributed to an increase in wetlands.

CONCLUSION AND RECOMMENDATIONS

The study assessed green spaces amid land cover changes in Delta State, Nigeria. The study reveals that green space had the highest area cover through out the years under investigaton, however with continuous decrease in size. Hence, the study concludes that the green spaces in Delta State have and are suffering from depletion, mostly attributed to urbanization; which puts our environment at risk of biodiversity loss, deforestation and pollution, food insecurity, alteration of habitats, and destruction of ecosystems. Tree planting is recommended especially in urban areas of the State to increase the area of green spaces.

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Authors' Contributions

OC conceptualized the study. OC & DUO designed the experiment, collected data, performed data analysis, and wrote the first draft of the manuscript. CLU performed literature searches and reviewed the first draft of the manuscript. All authors read and approved the final draft of the manuscript.

Ethical Statement

Not applicable.

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